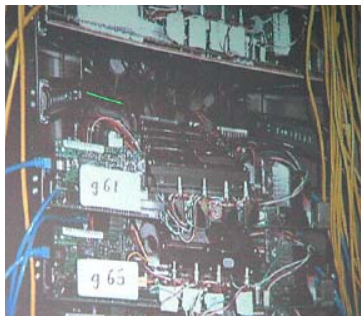




Data Center Power Distribution Overview

Paul Savage, CEO

Wayne Gutschow, VP



July 12, 2007

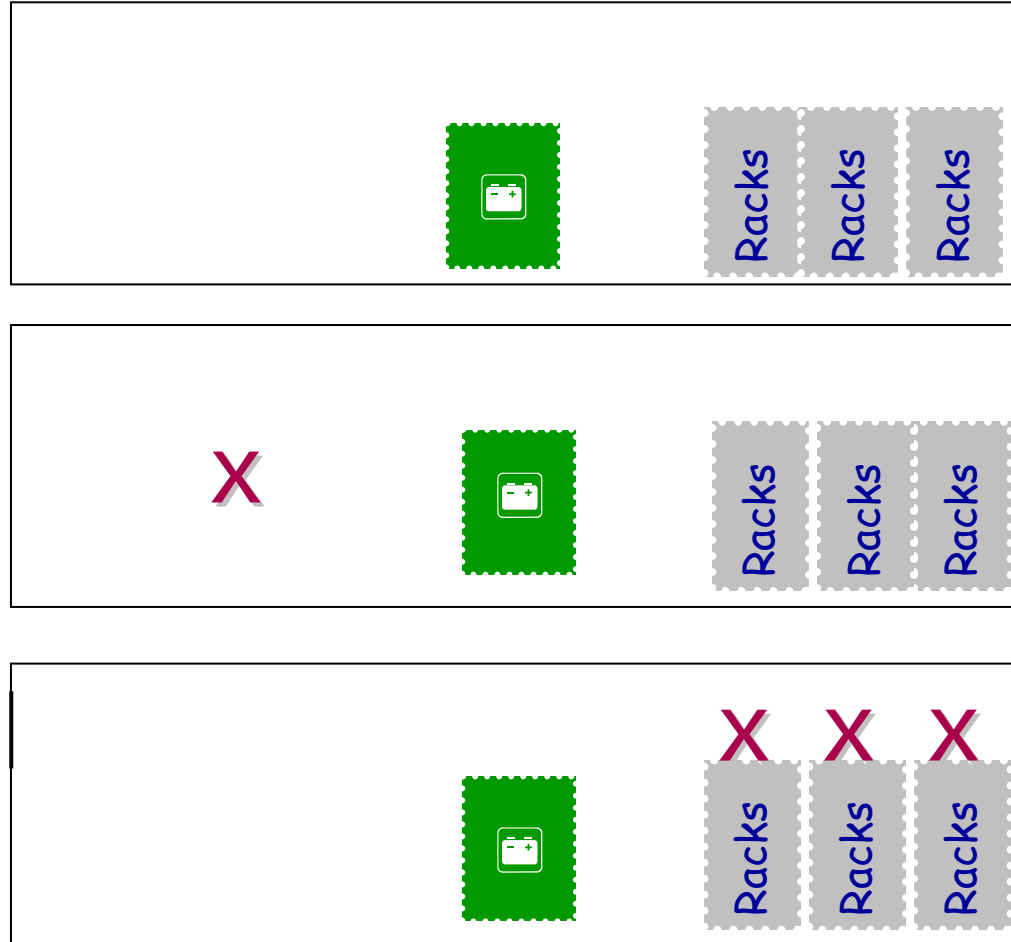
Topics to be addressed :

- Where is the best place to perform the primary rectification the equipment requires
- Power distribution to receptacles: Bus bar versus wires
- Voltage and distance issues
- Sparking and transients caused by hot disconnect of receptacle and plug
- Stranded versus solid conductors
- Wire metallurgy
- The DC Power networking status quo away from telecom and railways & standards making activity for DC power
- What do you consider the biggest challenges to DC distribution becoming a reality in data and telco centers?
- When do you think this will become a reality?

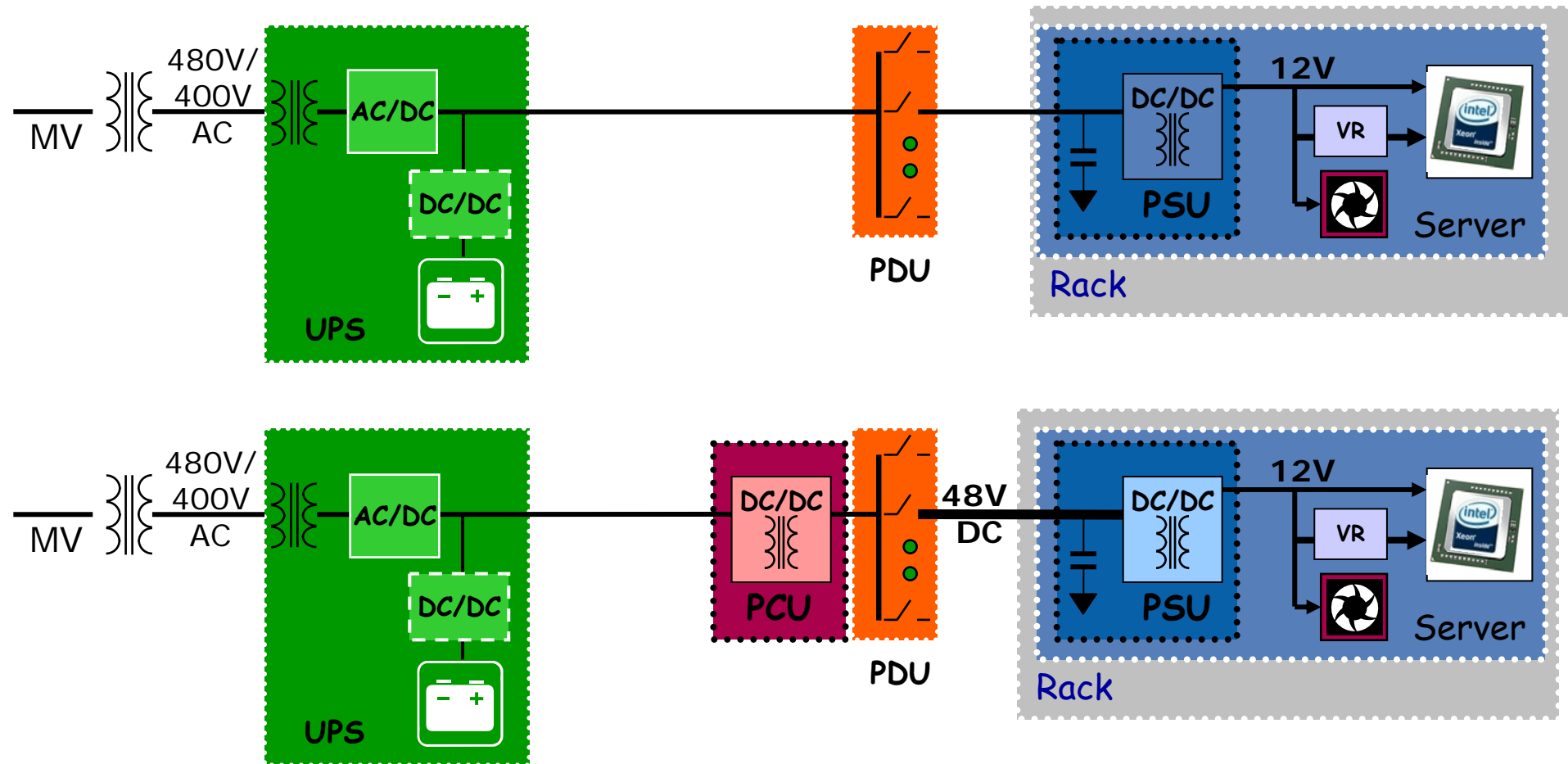
Power Architecture vs. Building Architecture

BUILDING ENVELOPE

PRIMARY
RECTIFICATION



What Distribution Architecture?



Further DC Systems Efficiency

- Lighting



- HVAC



On-Site Power Production (DG)



DC Networks are Proliferating in Other Applications



Bill McDonough

PHILIPS



Lynardi's



DC for Data Centers: Lessons learned from 30 years of AC power quality

Alex McEachern
Power Standards Lab
Alex@PowerStandards.com

July 12, 2007

Alex McEachern



- Alex McEachern, President of Power Standards Lab
 - Chair of IEC 61000-4-30 (power quality measurement methods), also SEMI F47, IEC 61000-4-34, IEC 61000-4-11, IEEE 1159.1, etc. etc.
 - Author of hundreds of articles on electric power measurements, 29 patents, founder of BMI (now Dranetz-BMI), etc. etc.
 - Works on world-wide AC power distribution problems, especially in semiconductor and high-tech factories
- Now working with members of this group on DC power disturbance measurements.

Topics to be addressed :

- DC disturbances happen.
- Disturbance characteristics are a function of the physical layout of distribution system.
- Disturbances disrupt the loads (intermittently).
- Disturbances are a compatibility problem, not an electric power problem.
- Equipment designers don't know about, or don't consider disturbances on DC bus.
- Unlike AC, we don't have good data -- yet! -- on DC disturbances.
- 4 recommendations for this group.

Lessons learned from 30 years of AC power quality (1)

◆ Disturbances happen.

AC power

Voltage range ($\pm 10\%$)

Voltage sags

High-freq impulses

Harmonics

No!

No!

etc...

DC power

Voltage range

Voltage sags

High-freq impulses

No!

Magnetic saturation

Sustained arcing

etc...



◆ Disturbance characteristics are a function of the physical layout of the DC power distribution system.

Impedance and available fault current

Impedance vs. frequency

Resonance

Time curves of protection devices etc. etc. etc.

Lessons learned from 30 years of AC power quality (2)

- ◆ Disturbances disrupt equipment.

Unexpected resets, unreliable operation, etc.

- ◆ Disturbances are a compatibility problem.

Either improve the distribution system, or make the equipment tougher.



- ◆ Equipment designers don't know about, or don't consider, disturbances (other than voltage range).

- ◆ Unlike AC, we don't yet have good data on DC power disturbances.

MIL-STD, Bellcore, Telcordia, ETSI...



Recommendations

1. Gather data on DC disturbances.
 - ◆ Measure at equipment terminals.
 - ◆ Upper frequency bound?
 - ◆ Reporting of event characteristics?
 - ◆ Distribution types and sizes? How long?
2. Report results to designers of DC loads.
3. Use “compatibility level” approach, not perfection.
4. End point: simple compatibility tests for equipment, similar to IEC 61000-4-34 or SEMI F47.

DC for Data Centers: Power Distribution

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Panduit Labs
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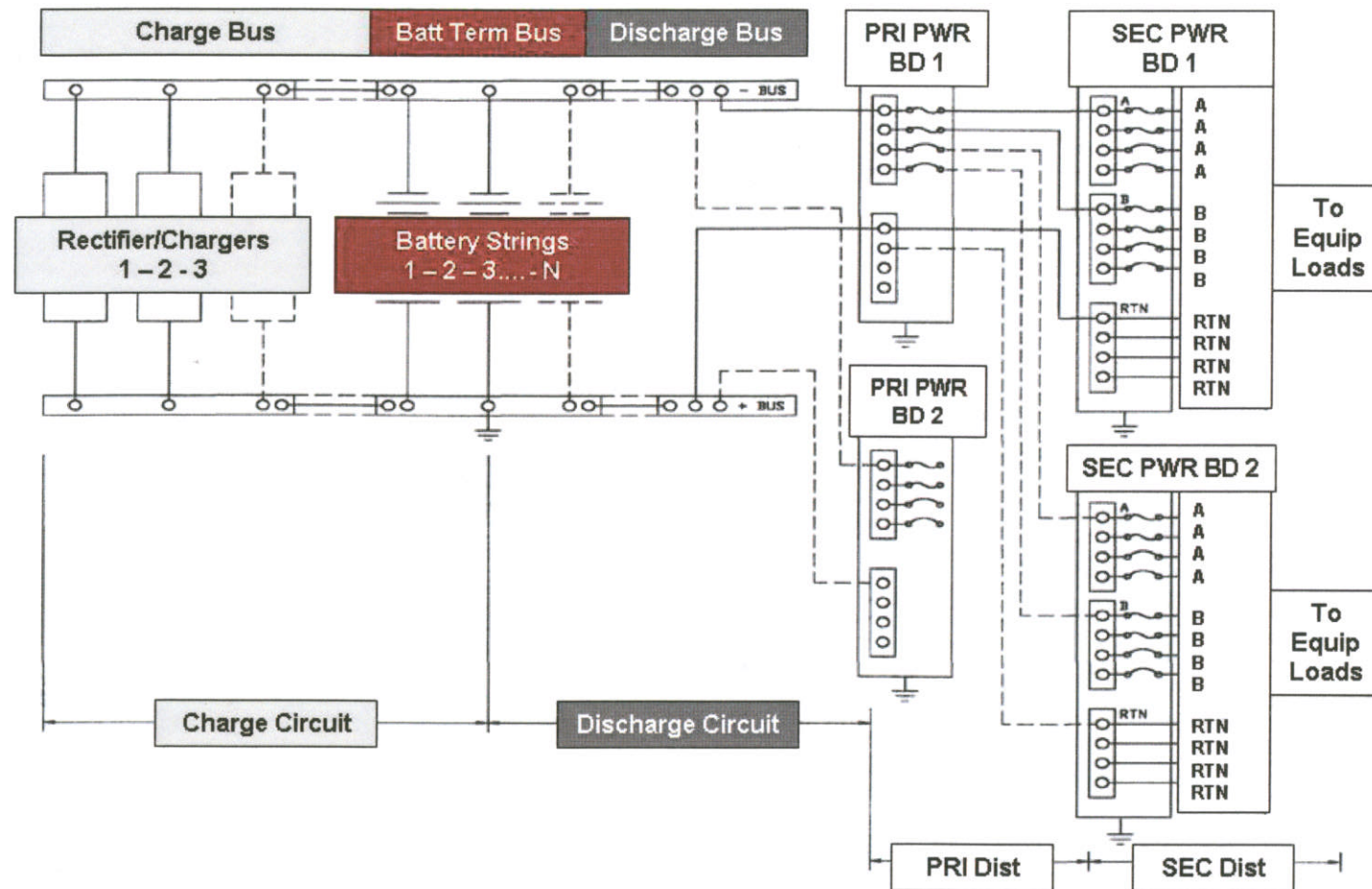
July 12, 2007

William Bush

- Director of Research – Power & Grounding
 - Chair of Ch 9 (ITE), IEEE Std. 1100TM-2005 Recommended Practice for Powering and Grounding Electronic Equipment
 - Also involved with related standards work with organizations such as IEEE, ATIS T1, TIA and BICSI

Topics to be addressed

- Co-routing of supply, Return and DCEG
- Sizing conductors, bus and bars for ampacity and circuit voltage drop
- Stranded wiring for flexibility
- Electromagnetic forces during fault conditions
- Transient characteristics
- OPDs and disconnects
- Minimize common impedance of supply



Telco Example

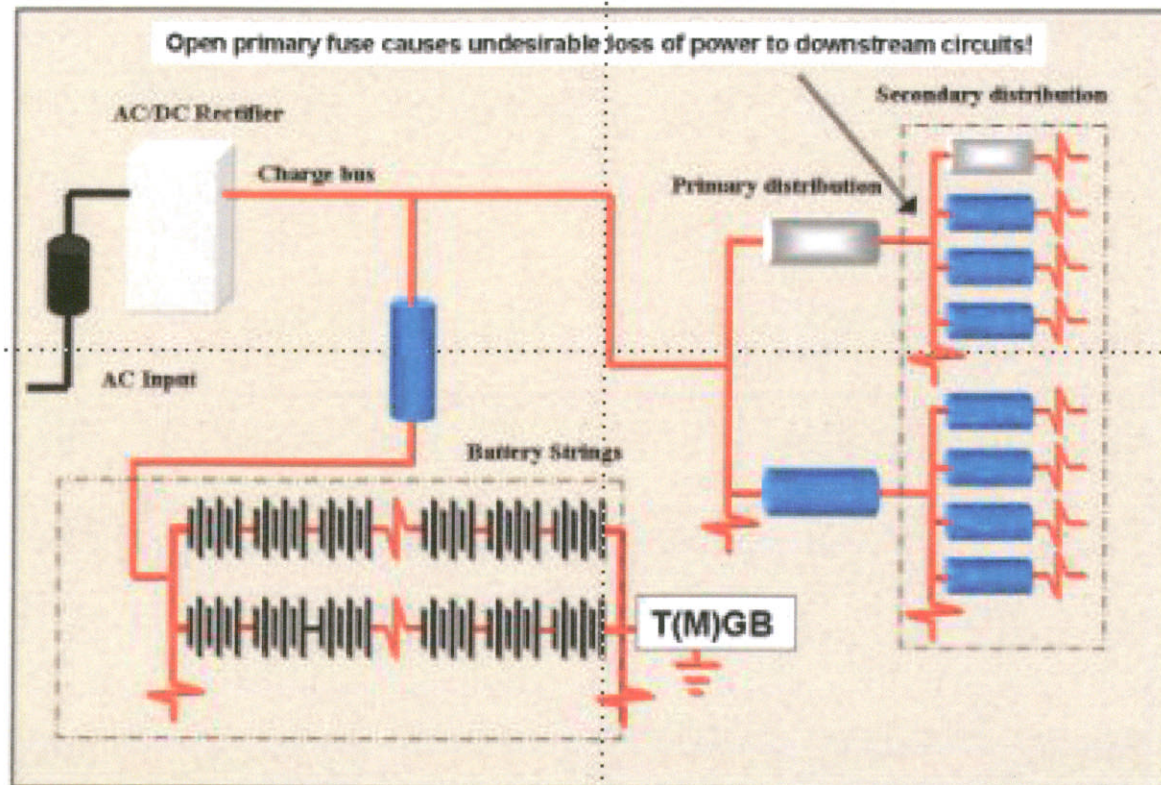
Workshop: DC for Data Centers – W. Bush, Panduit Corp.



Telco Example

Workshop: DC for Data Centers – W. Bush, Panduit Corp.

9.33 CDCPS non selective co-ord



Telco Example

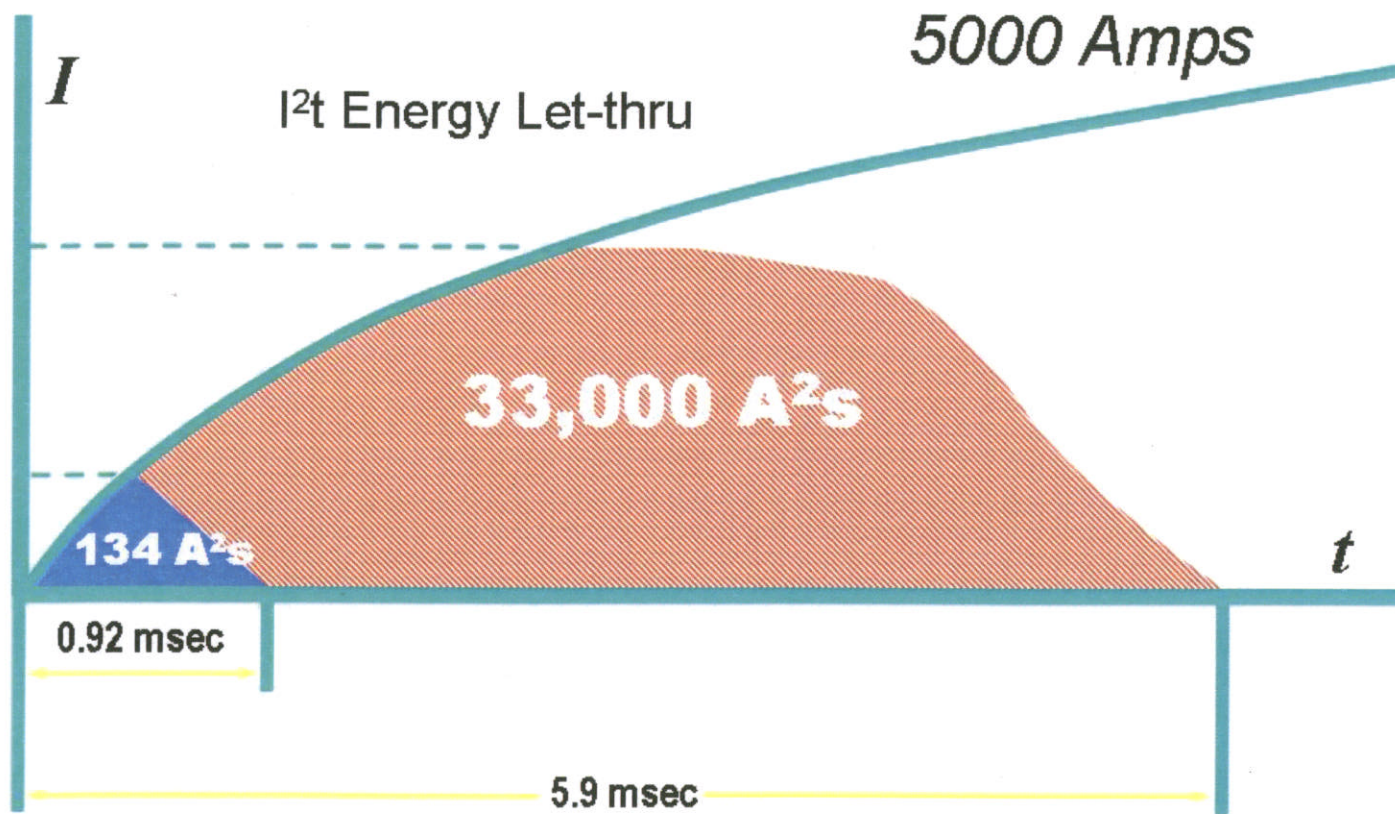
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PAC 23 PSW Conf. 10/23/06 Long Beach

W. Bush

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Current Limitation Test Results



Telco Example

The Greening of the Data Center: How DC Power Can Make Energy Efficiency Cool!

Mick McDaniel
SatCon Power Systems
mick.mcdaniel@satcon.com

July 12, 2007

Overview

1. Quick Bio & Intro
2. Answer the Panel Questions
3. Answer My Own Question: How Can DC Power Make Energy Efficiency “COOL”?
4. Questions

Mick McDaniel & SatCon Power Systems

- Mick McDaniel, VP of Sales & Mktg, SatCon Power
 - Over 10 Years of experience selling enterprise & distributed power systems (UPS/Gens/Controls) for data center applications
 - Helped transform SatCon's focus towards large power conversion systems for renewable energy applications
- SatCon Power Systems
 - Inverter Products
 - Photovoltaics (PV), Fuel Cell, Energy Storage, Wind
 - Industrial Power Products
 - MV Rectifiers for Industrial Applications & PQ
 - Frequency Converters for Test & Measurement and Aerospace
 - World leader in large Fuel Cell inverters & North American leader in large-scale PV inverters

Topics to Discuss

- 1. Where is the best place to perform the primary rectification the equipment requires**
2. Power distribution to receptacles: Bus bar versus wires
3. Voltage and distance issues
4. Sparking and transients caused by hot disconnect of receptacle and plug
5. Stranded versus solid conductors
6. Wire metallurgy
- 7. Your company's current and projected activities in this space? E.g. are you planning a demo; developing/marketing equipment?**
- 8. What do you consider the biggest challenges to DC distribution becoming a reality in data and telco centers?**
- 9. When do you think this will become a reality?**

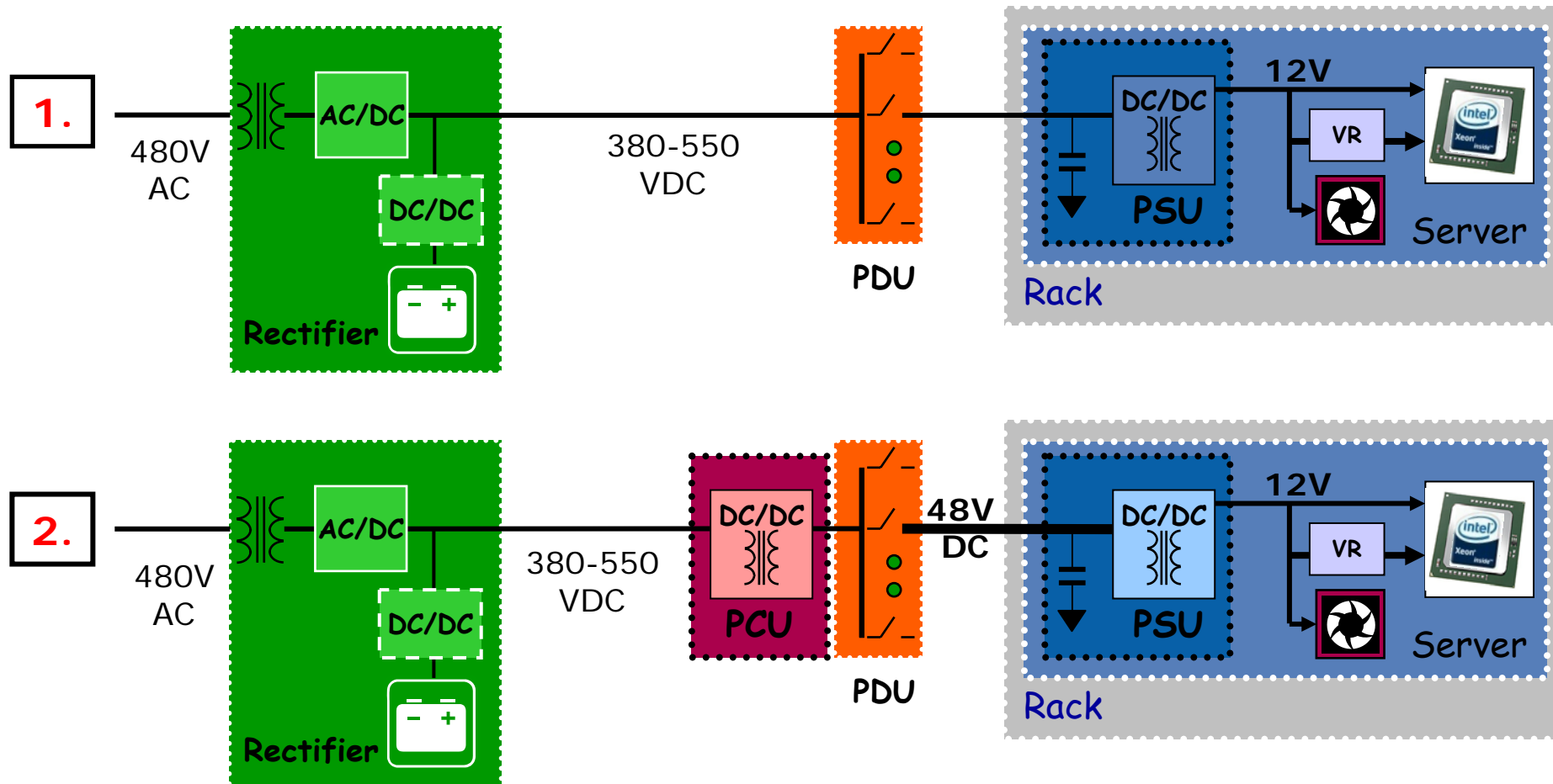
Q1: Where is the Best Place to Perform the Primary Rectification?

Answer: It Depends.

Some of the criteria that will go into the decision:

- New construction or upgrade / retrofit
- Installed & operational costs
 - Efficiency is one major component of this analysis
- Criticality of center = reliability / hardness of design
- Company standards / policies
- Existing IT platforms
- Availability of products
- Existing standards / codes
- Employee philosophy

Existing Data Center Possibilities



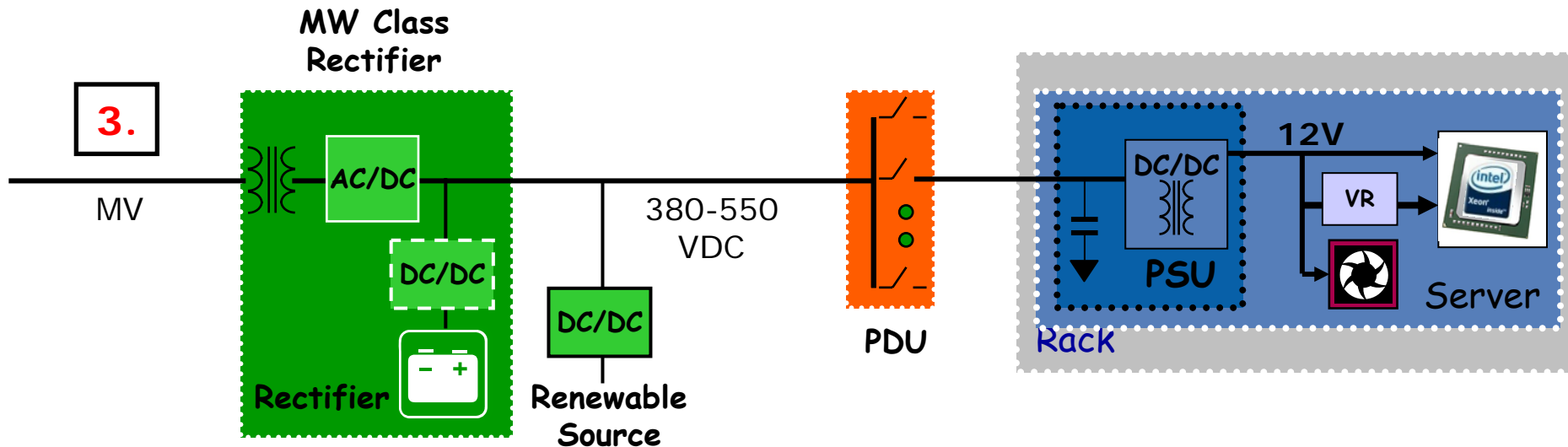
Reasons: 1. Right power rating; 2. Integrate legacy equipment

Existing Data Center Rectifier Examples



- Easy to design & build standard products from 50kW to 1MW & up!
 - Similar to UPS products currently on the market
- Single and Dual stage products possible (depends on spec voltage, design, etc.)
- High efficiency designs
- High reliability designs, proven technologies
- Indoor-rated, air-cooled

New Data Center Options



- Many topologies possible for rectifier
 - Depends on load demands, input requirements, costs, etc.
 - Simple to integrate Renewable sources with DC/DC converter
- ⇒ Remember, large power blocks are almost always less expensive (\$/kW), more efficient, and more reliable!

New Data Center Rectifier Example



MV IGBT Chopper Rectifier: 38.25 kA, 440VDC x 2, for electro-winning application in new Arizona copper mine

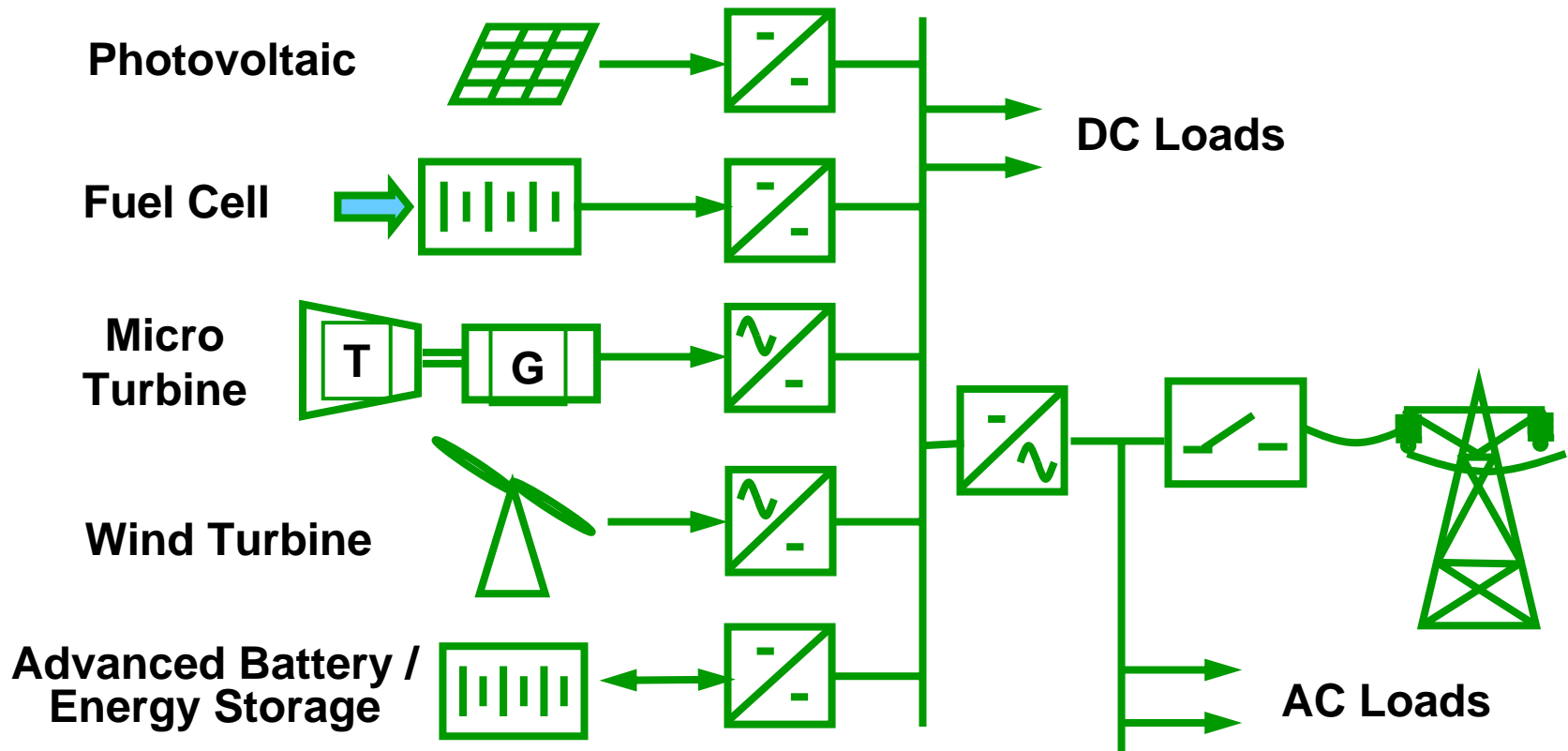
New Data Center Rectifier Example #2



LV IGBT Single-Stage Inverter, 1.2MW, for stationary fuel cell application

Q7: SatCon's Activities in DC Markets?

SatCon is very active with all types of power conversion for renewable energy and industrial power quality.



Q8: What do I Consider the Biggest Challenges to DC Power Distribution?

Us!

Specifically, our companies and our own strategic agendas.

In my view, the technical hurdles can all be overcome.

As the Pogo cartoon said many years ago,
"We have met the enemy and he is US."

Q9: When do you think this will become a reality?

18 - 24 months

Conclusion: Why Is DC Distribution Important?

There are 2 markets that the investment community is really focused on at the present time:

1. Renewable Energy

- For MANY, MANY reasons
 - The environment, energy security, peak oil, etc.
- It has a big, bright, GREEN future!

2. Energy Efficiency

- Overlooked by most = not cool or sexy enough
- But definitely the lowest hanging fruit on the tree!!!
- Good for everybody (the environment included)

How Can DC Power Make Energy Efficiency Cool?

Simply, by saving...

MONEY!

Energy costs are becoming the major cost and concern of operating a data center - and that is the bottom line!

Questions?

Mick McDaniel
SatCon Power Systems
mick.mcdaniel@satcon.com

July 12, 2007

Power Distribution Panel

July 12, 2007

Data Center DC Power Distribution

- Where is the best place to perform the primary rectification the equipment requires
 - Closer to the server – minimize DC loop resistance, inductance
 - Not in the server rack
 - 480VAC, 48VDC distribution methods well understood
- Power distribution to receptacles: Bus bar versus wires
 - Depends on the current. Wires are less costly
 - Ease of future expansion is important.
 - Modular, hot plug

Data Center DC Power Distribution

- Voltage and distance issues
 - DC loop resistance, inductance, negative impedance of server p.s.
 - UL1950 pollution degree 3 requires 6.8MM clearance @ 380VDC
 - Grounded or ungrounded?
 - Ungrounded needs GFI – multiple locations?
 - Dual bus, diode or'ed?
- Sparking and transients caused by hot disconnect of receptacle and plug
 - Needs to be managed (enable pin)
 - UL, NEC personnel safety
- Stranded versus solid conductors
 - Stranded building cable is more versatile, less costly, universally accepted

Data Center DC Power Distribution

- Emerson Current activity
 - Under study at several divisions
 - Participation in industry initiatives
- What do you consider the biggest challenges to DC distribution becoming a reality in data and telco centers?
 - HVDC safety, physiological concerns, maintenance
 - Equipment compatibility
 - 48VDC well known in telco, centralized and distributed
- When do you think this will become a reality?
 - HVDC standards must be established
 - Server power supply DC input
 - NEC
 - Reliability